EIC Detector R&D Proprosal

The eRD108 Consortium

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Project Name: Cylindrical MPGD R&D towards an EIC detector

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1 Introduction

We propose continued generic R&D on two types of cylindrical Micropattern Gaseous Detectors (MPGDs). These are applicable to all detector concepts, for which proposals are currently in preparation for a detector at the EIC. One type is the micro-Resistive-Well (μRWELL) detector and the other is the micromegas (MM) detector.

Specifically, we propose to investigate

1. a single cylindrical μRWELL layer directly in front of the DIRC particle identification subdetector,

2. several cylindrical MM detector layers to create a central barrel tracker

We emphasize that our proposed R&D targets two different applications for these two types of subdetectors. They are not to be considered interchangeable.

The μRWELL layer can improve the measurement of direction and impact position of charged particles that hit the DIRC by measuring a tracklet after the particles have traversed all material in the central tracker and its support structure. This information, that is little compromised by multiple scattering in material, can be used to seed the Cerenkov ring reconstruction in the DIRC. The goal is to measure the tracklet direction so that a directional resolution of 1 mrad or better can be achieved in combination with central tracking. This single μRWELL layer mainly targets the detector concepts with an all-Si design. It could be implemented in the ATHENA, CORE, and ECCE detector concepts. The R&D is necessary because nobody has yet constructed and operated a cylindrical μRWELL of any size to the best of our knowledge.

The MM detector layers aim at being a low-mass tracking detector that complements a silicon vertex tracker. A Si-MPGD hybrid design is currently under consideration for the ATHENA detector concept. The curved MM design will leverage the already existing CLAS12 MM technology, even though the detectors for EIC must have a 2D readout. The R&D will focus on the optimisation of the readout patterns. In parallel, the focus of the EIC on electromagnetic observables will benefit from this R&D to lower even further the material budget of MM detectors. The focus of this R&D is to look for lighter materials for each component of the MM detector, starting with the material used for the amplification mesh.

2 μRWELL Layer for seeding DIRC reconstruction

2.1 R&D plan for FY22

We propose to design, build, and commission a functional small (20 cm diameter, 55 cm length) cylindrical μRWELL detector in FY22 and to test it in the proton beam at FNAL in FY23.

The main objectives are to demonstrate that a cylindrical μRWELL detector indeed works and to quantify its tracking performance. This μRWELL prototype will be equipped with a composite foil that integrates μRWELL amplification structure and capacitive charge-sharing readout as well as a 2D zigzag readout. These types of readouts can minimize the number of readout channels. Half of the detector will be read out with one of the structures and the other half with the other structure. The exact segmentation will be decided in the design phase.

The single-layer application allows us to move away from our earlier ultra-low-mass μRWELL design with all foils as needed for a full barrel tracker because this appears to be quite challenging to implement on a large scale as we learned from our previous R&D work with a mechanical all-foil mock-up. Instead, we propose to move to a design that uses thin rigid materials, e.g. carbon fiber prepreg material, to create a rigid but still low-mass inner main cylinder for the detector. The composite μRWELL/readout foil will be attached to the outside of this cylinder. The drift foil will be attached to the inside of another rigid outer cylinder.

The radial gap between the two cylinders, i.e. the drift gap, will be 20-30 mm. This should produce enough ionization clusters to apply the mini-drift (micro-TPC) method that we have investigated in the past to measure and reconstruct a tracklet with high-quality directional information.

We will work to minimize the material for the drift electrode assembly because it is a critical design parameter as the charged particle to be tracked will be crossing this drift cylinder before hitting the DIRC. The amount of material located in the drift cylinder and in the inner cover of the DIRC determines how much multiple scattering the particle undergoes after being tracked in the cylindrical μRWELL and before hitting the active part of the DIRC. The material in the current design of the inner DIRC cover will inform the design and the choice of material for the drift cylinder. We will work with the DIRC R&D groups to optimize that.

On the electronics side, we propose to procure and commission an existing frontend & DAQ system, i.e. the SRS-VMM, that will allow us to read out the entire detector at the test beam with electronics that move beyond aging APV-based electronics. In FY22 we will focus on gaining expertise and commissioning a small scale SRS-VMM system that is already in hand. In FY23, we will procure electronics needed to scale the frontend and DAQ system up so that the entire detector can be read out. We do not plan to develop any new system based on the VMM or some other chip during this R&D period. We are also preparing to switch over to the DREAM chip as a fall back if we find that the VMM can not meet the needs of the micro-TPC mode.

2.2 Person-power required and available for FY22

- Designer of composite μRWELL/readout foil - UVa graduate student (25% FTE, TBD) & BNL staff Alexander Kiselev (10% FTE, available)

- Designer of cylinder mechanics - FIT graduate student Pietro Iapozzuto (75% FTE, available)

- Tester for electronics & DAQ - TU post-doc (50% FTE, TBD)

- Coordinators & Managers - Senior personnel from all institutions (unfunded)

2.3 Milestones and Timeline for FY22

- **Mechanical design completed (FIT)** - Date when BNL Funding Received (DBNLFR) + 4 months

- **Front-end electronics & DAQ design completed (TU)** - DBNLFR + 4 months

- **Readout foil design completed (UVa & BNL)** - DBNLFR + 5 months

- **Major Milestone:** Design completed - DBNLFR + 5 months

- **Mechanical assembly completed (FIT)** - Date when BNL Funding Received (DBNLFR) + 10 months

- **Existing (VMM-SRS) front-end electronics & DAQ tested (TU)** - DBNLFR + 10 months

- **Readout foil produced at CERN (UVa & BNL)** - DBNLFR + 10 months

- **Major Milestone:** Detector assembled - DBNLFR + 10 months

- **Integration of detector & electronics and benchtop testing** (All) - DBNLFR + 12 months

- **Major Milestone:** Detector ready for beam test - DBNLFR + 12 months

2.4 Preview of remaining R&D after FY22 until completion before FY24

The main task for FY23 will be to get the prototype ready for the beam test at FNAL, conduct the test there, and analyze the data afterwards. The group will conduct these tasks jointly.

3 Micromegas Barrel Tracker

3.1 R&D plan for FY22

Simulations performed for the EIC Yellow Report have shown that a 2D readout MM technology of similar implementation as the one in use in CLAS12 would meet the requirements for an EIC detector. However, any effort to reduce even further the material budget will be beneficial for the EIC physics program. Therefore, for FY22 we propose to focus on two main aspects: the optimisation of the 2D readout patterns and the reduction of material budget.

The main objective is to optimise the MM readout in order to achieve the best resolutions while minimising the number of readout channels and the amount of copper in the active region. We plan to design and build small scale prototypes with 2D zigzag readout patterns as well as orthogonal strips. The 2D zigzag will allow the sharing of the charge over the two directions. The orthogonal strips will pickup the induced signal in the resistive layer. The sizes of the prototypes will be 400mm×400mm for the zigzag and 100mm×100mm for the orthogonal strips. The prototype readout material budget will be as close as possible to the one foreseen for the full size detector. These detectors will be tested with cosmic rays, x-ray guns and, possibly, in beam tests.

With the goal of making MM detectors as light as possible, for the FY22 we plan to perform feasibility studies of using thin ($5\text{-}25\mu$m thick) foils of aluminum instead of the usual woven Inox mesh. The expected reduction of material budget for the aluminum mesh is about twenty times less then the Inox one. Holes of few micrometers will be created in aluminum foils through laser ablation. We have already identified a company able to perform such operations of laser ablation. We plan a few iterations of samples to check the reliability of the process. Once the final samples are selected, we plan to use these aluminum meshes with the bulk process.

3.2 Milestones and timeline for FY22

- **Readout designs (Saclay & BNL)** - DBNLFR + 2 months
- **Readout foils received (Saclay & BNL)** - DBNLFR + 5 months
- **Bulk and assembly of prototypes (Saclay)** - DBNLFR + 7 months
- **Cosmic ray data taking completed (Saclay)** - DBNLFR + 8 months
- **Bench test with X-ray gun (BNL)** - DBNLFR + 10 months
- **Analysis results (Saclay & BNL)** - DBNLFR + 12 months
- **Aluminum mesh received (Saclay)** - DBNLFR + 8 months
- **Bulking of aluminum mesh (Saclay)** - DBNLFR + 10 months

3.3 Preview of remaining R&D after FY22 until completion before FY24

The main task for the FY23 and FY24 will be to build one full scale curved MM tile (50 cm × 70 cm) with the final choice of the 2D readout.

4 Suggested funding profile and funding split among the participating institutions for FY22 and FY23

Institution	FY22 request	FY23 request
BNL	$30,000	$15,000
FIT	$53,602	$53,602
UVa	$50,240	$47,520
Saclay	$21,000	$36,000
TU	$56,063	$92,063
TOTAL	$210,905	$244,185

A detailed breakdown of the request for each institution can be found in an excel sheet available at this link:
Detailed Budget Breakdown (excel Sheet).